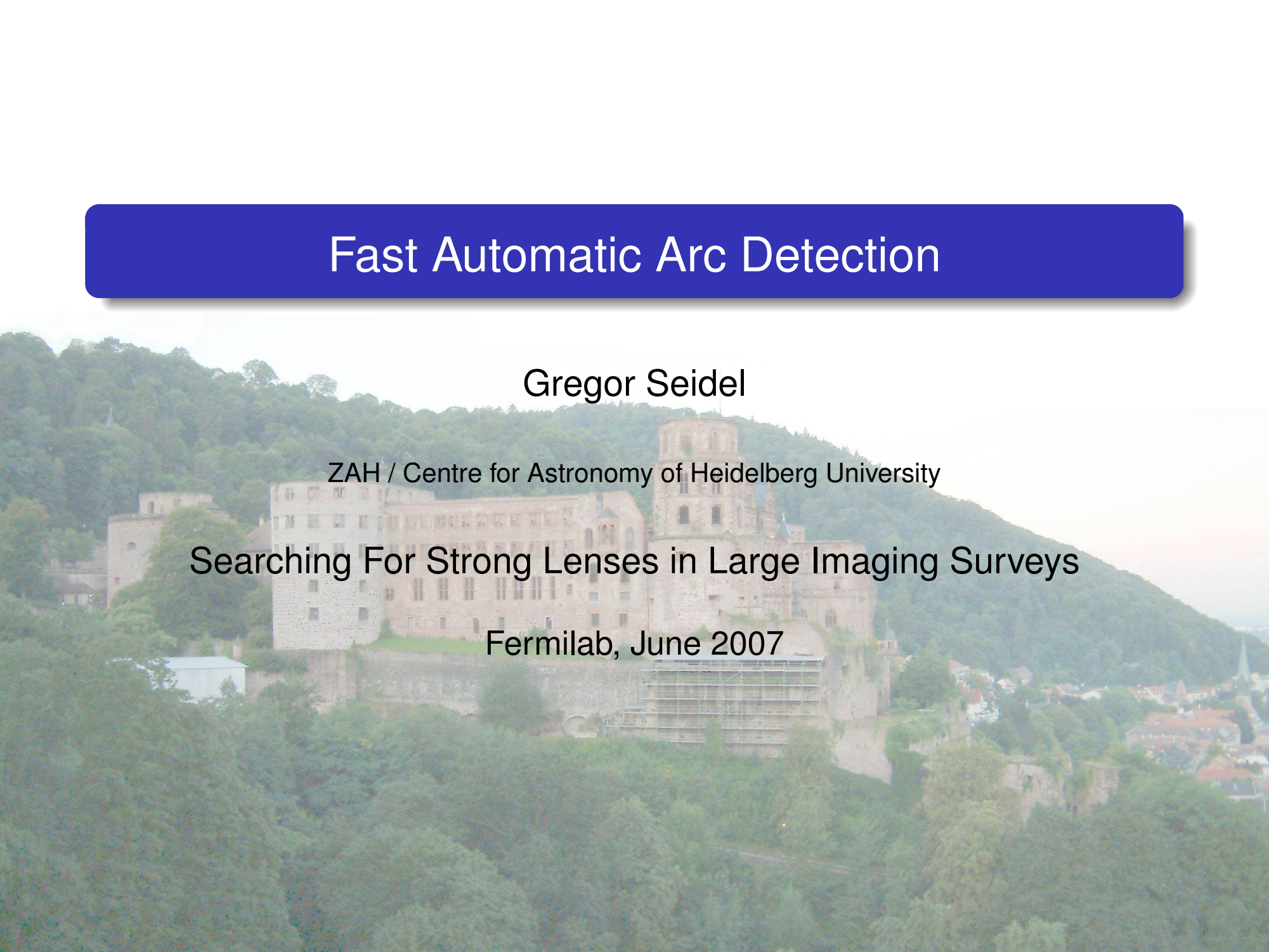
Fast Automatic Arc Detection



Gregor Seidel

ZAH / Centre for Astronomy of Heidelberg University

Searching For Strong Lenses in Large Imaging Surveys

Fermilab, June 2007

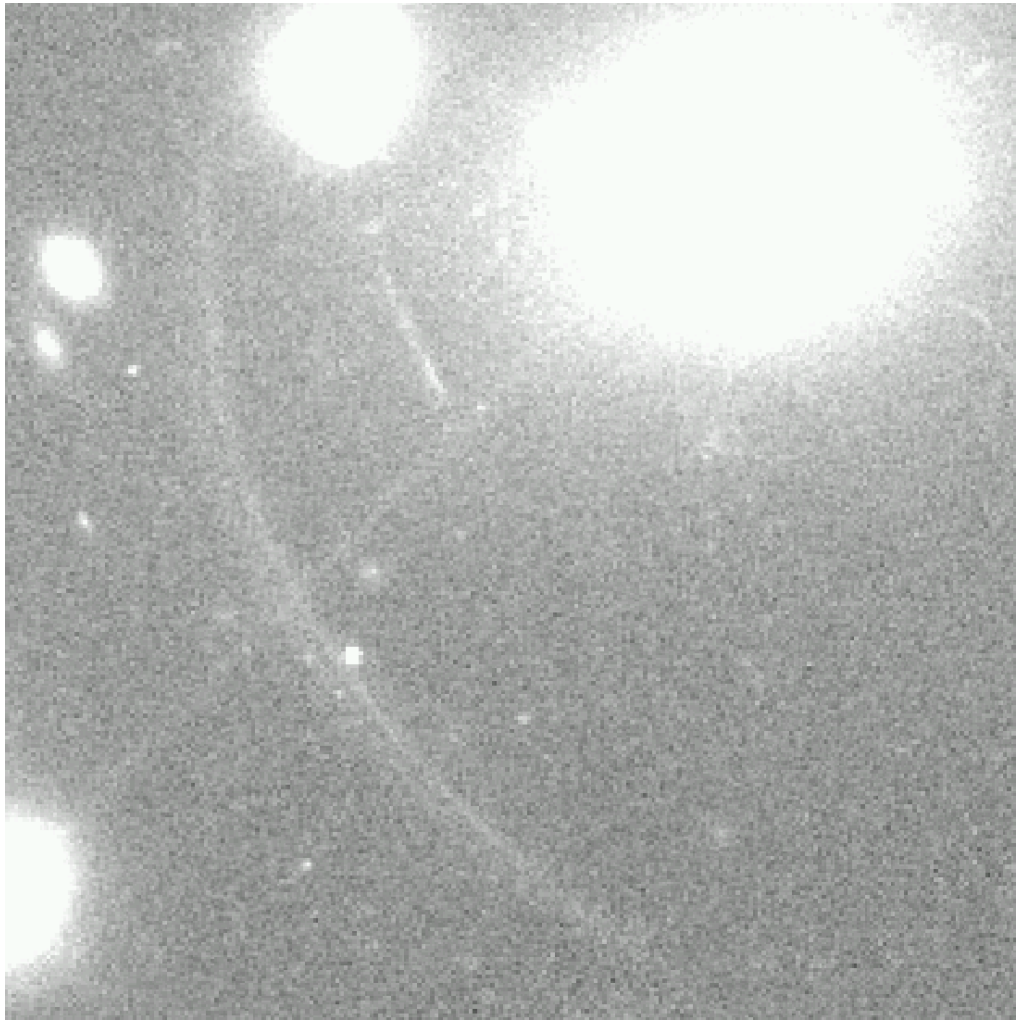
Employing visual inspection for arc searches is problematic:

- depends on intensity scaling
  → hidden faint arcs near bright objects possible
- ambiguous feature classification bad for statistics
- data volume increases rapidly with future surveys
- needs a priori information
  → selection effects
  → hides arcs near dark clusters

Fast, automated arc detection is desireable.

Partitioning into cells

- distribute cells on rectangular grid



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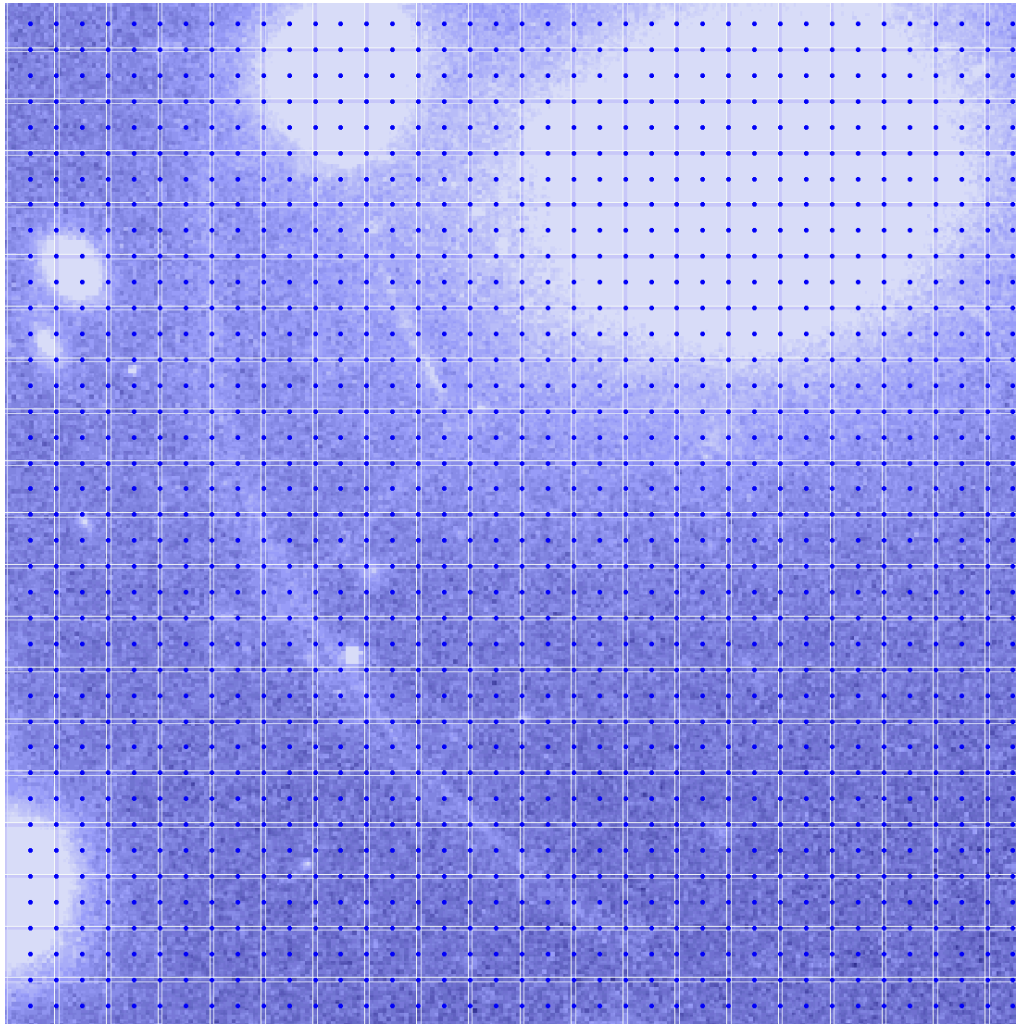
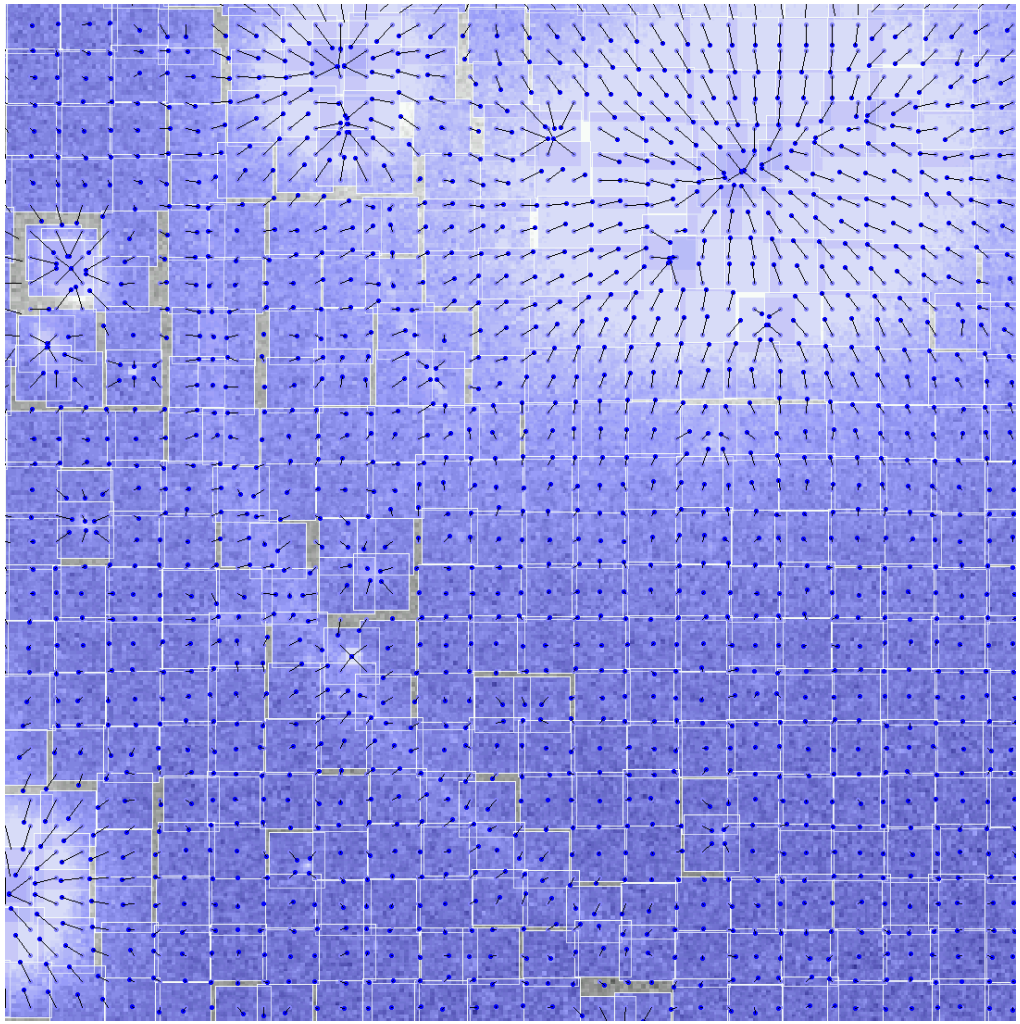


- distribute cells on rectangular grid
- shift to local centre-of-brightness

centre of brightness

$$\vec{\bar{x}} = \frac{\int_A \vec{x} q(I(\vec{x}))\, \mathrm{d}^2 x}{\int_A q(I(\vec{x}))\, \mathrm{d}^2 x}$$



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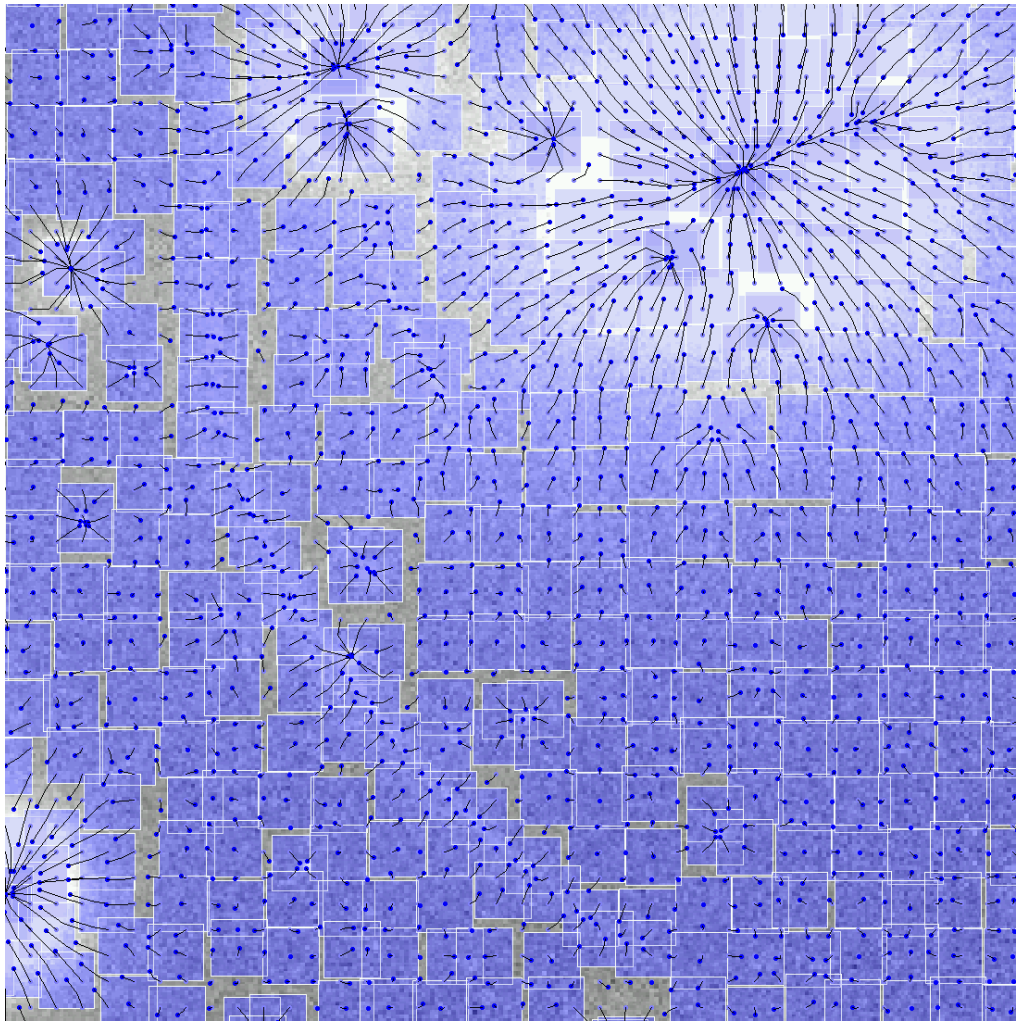

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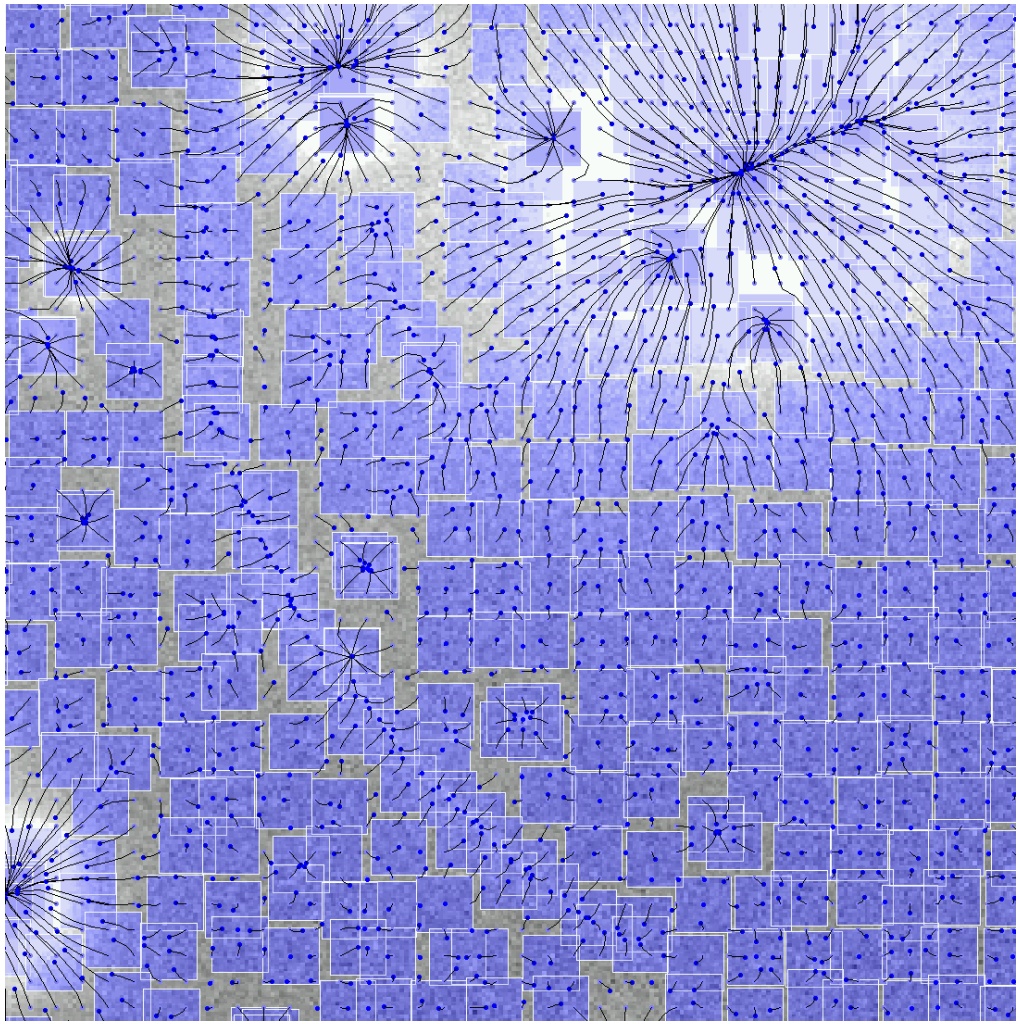


- distribute cells on rectangular grid
- shift to local centre-of-brightness
- ellipticities

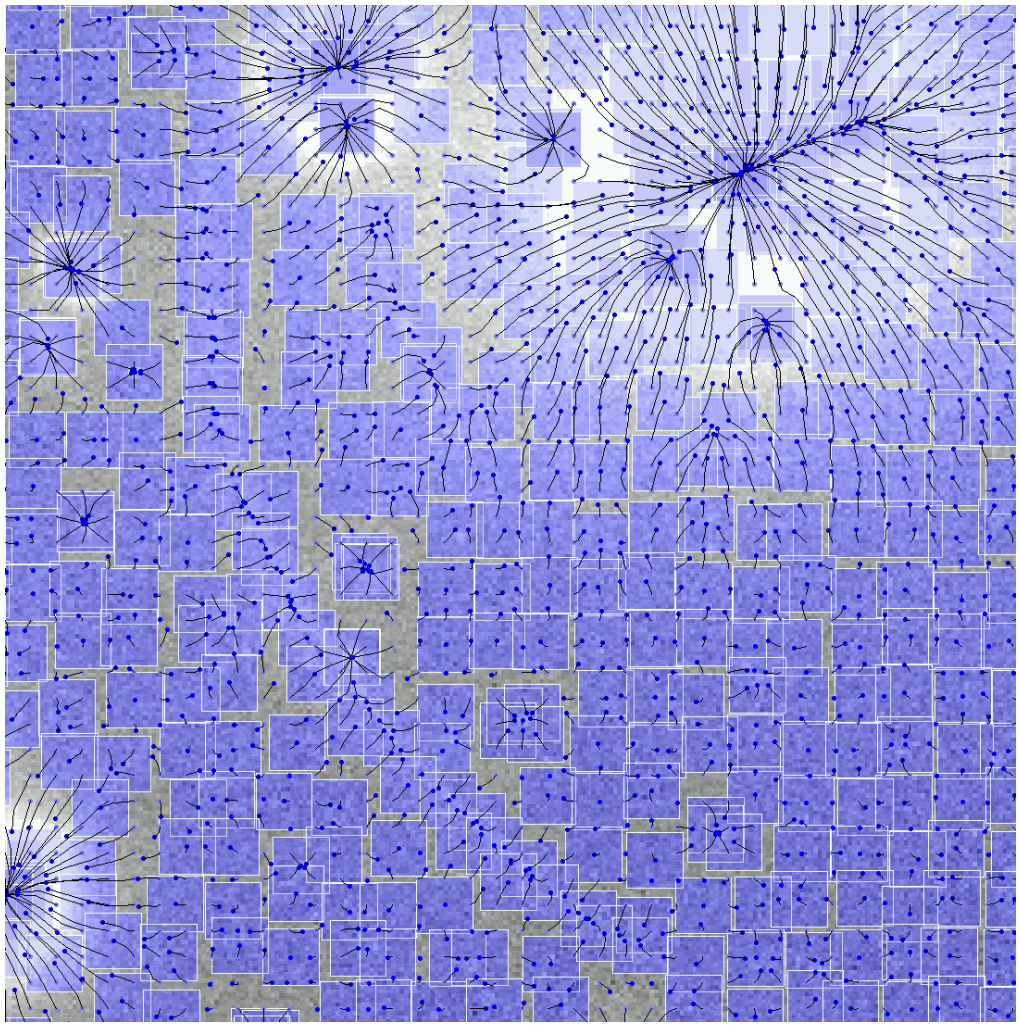
  $\Rightarrow$ orientations

second-moments Q_{ij}

$$\frac{\int_A (x_i - \bar{x}_i)(x_j - \bar{x}_j) q(I(\vec{x}))\, \mathrm{d}^2 x}{\int_A q(I(\vec{x}))\, \mathrm{d}^2 x}$$

complex ellipticity χ

$$\chi = \frac{Q_{11} - Q_{22} + 2\mathrm{i} Q_{12}}{Q_{11} + Q_{22}}$$



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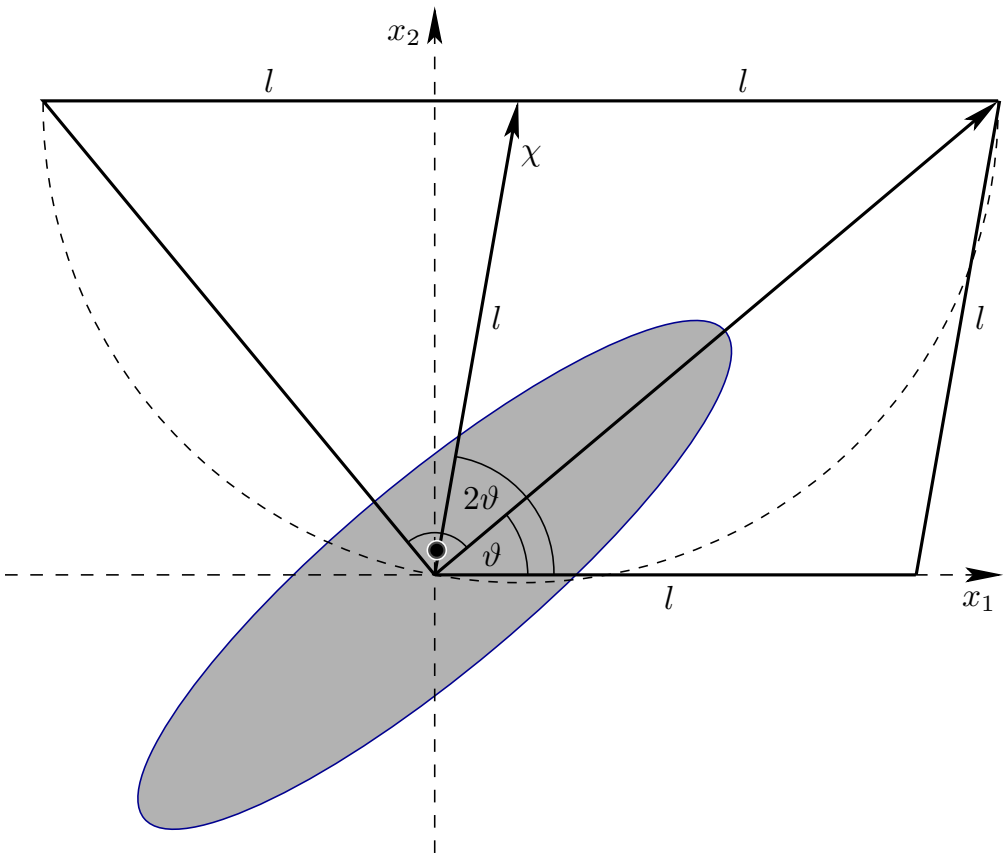
$$\chi = \frac{Q_{11} - Q_{22} + 2iQ_{12}}{Q_{11} + Q_{22}}$$

orientation

$$\chi = \frac{(1-r^2)}{(1+r^2)} \exp(2i\vartheta)$$



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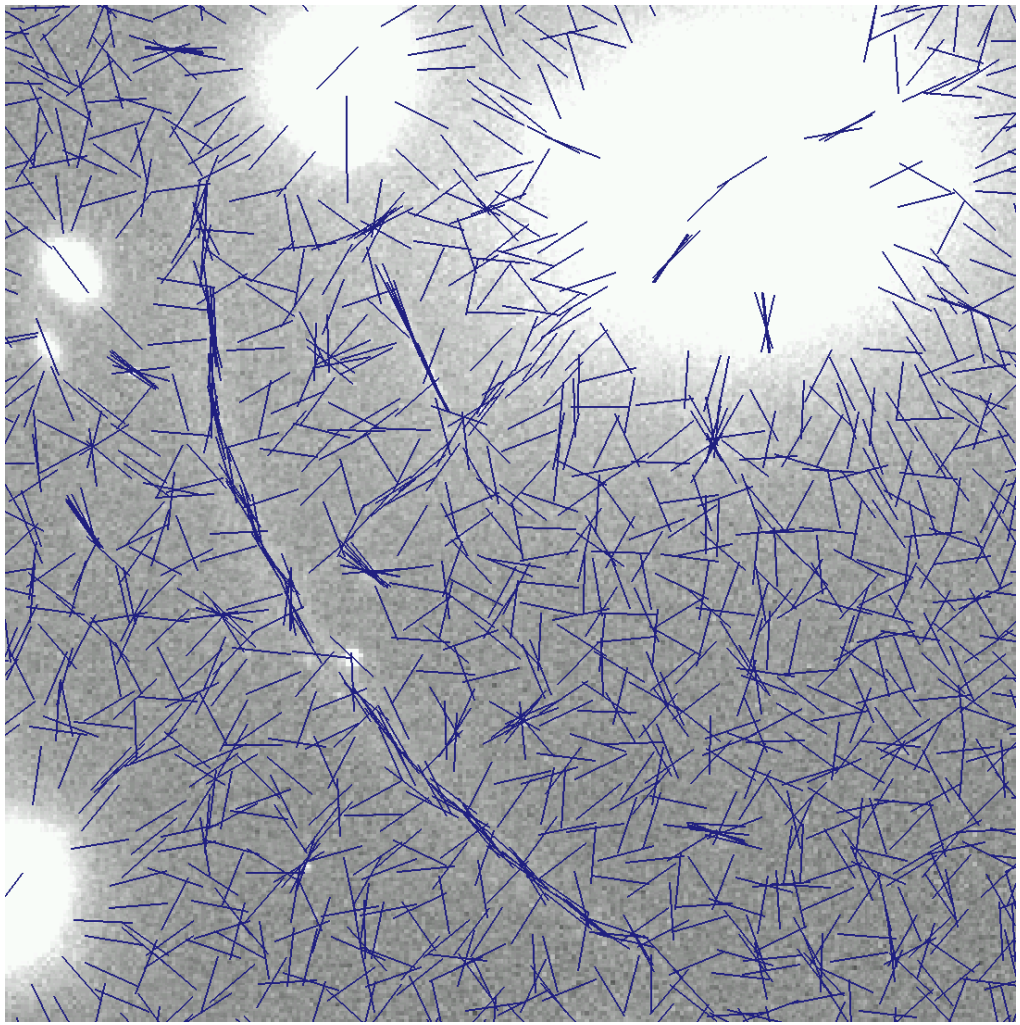


- cell correlations c^i
- $c^i > c_{\text{thres}} \Rightarrow$ add cell i to an object

cell correlation

$c^i = \frac{1}{|\mathcal{N}|} \sum_{j \in \mathcal{N}} c^{ij}$

$c^{ij} = c_d^{ij} c_x^{ij}$

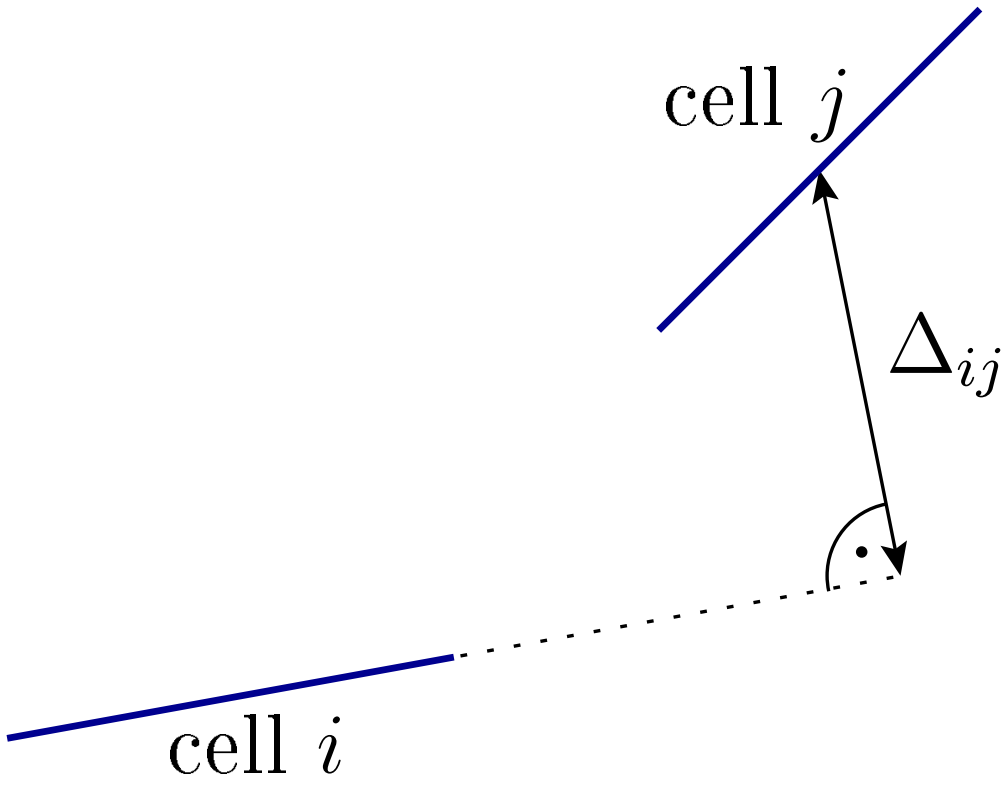
$c_d^{ij} = |\vec{e}^i \, \vec{e}^j|$

$c_x^{ij} = \max\left(1 - \frac{\Delta_{ij}}{d}, 0\right)$

$\mathcal{N}$: cell neighborhood

$\Delta_{ij} = \left|(\vec{x}^j - \vec{x}^i) \times \vec{e}^i_\perp\right|$

d: initial separation



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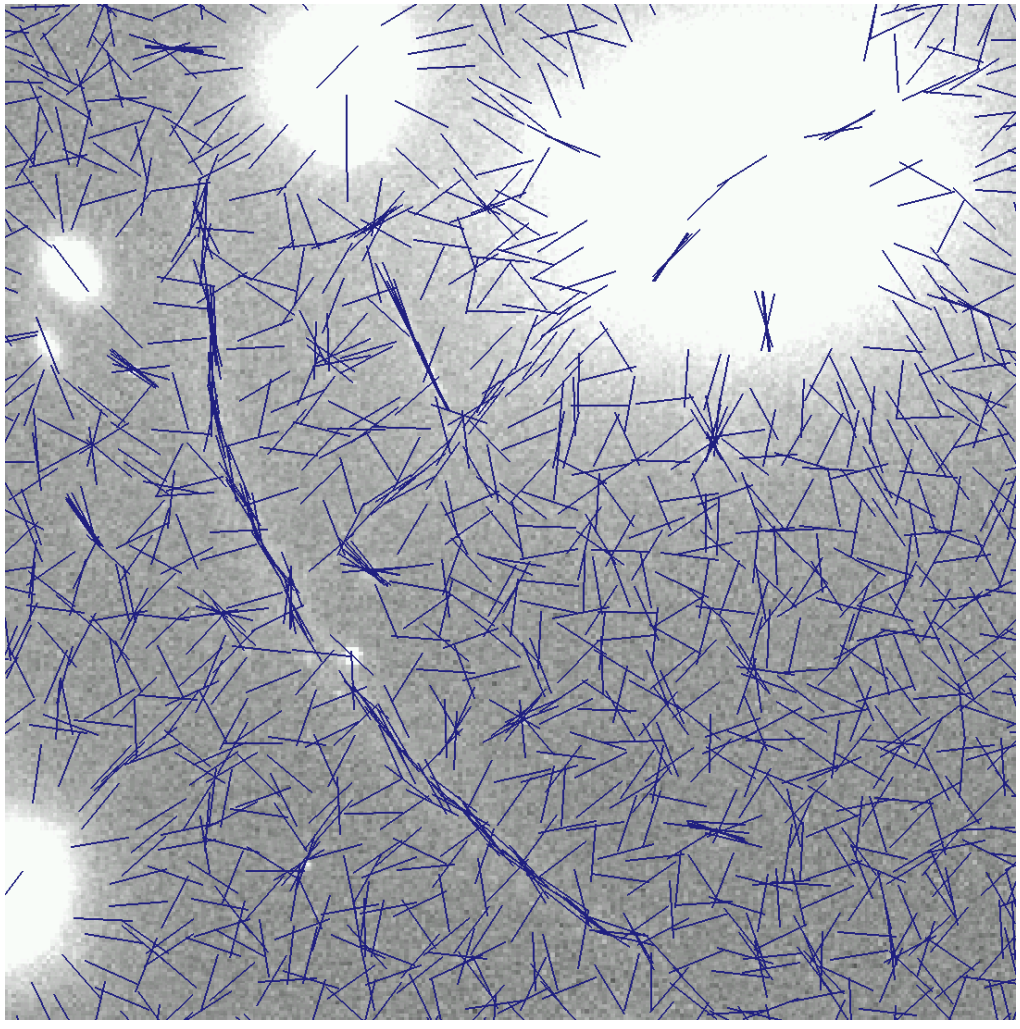

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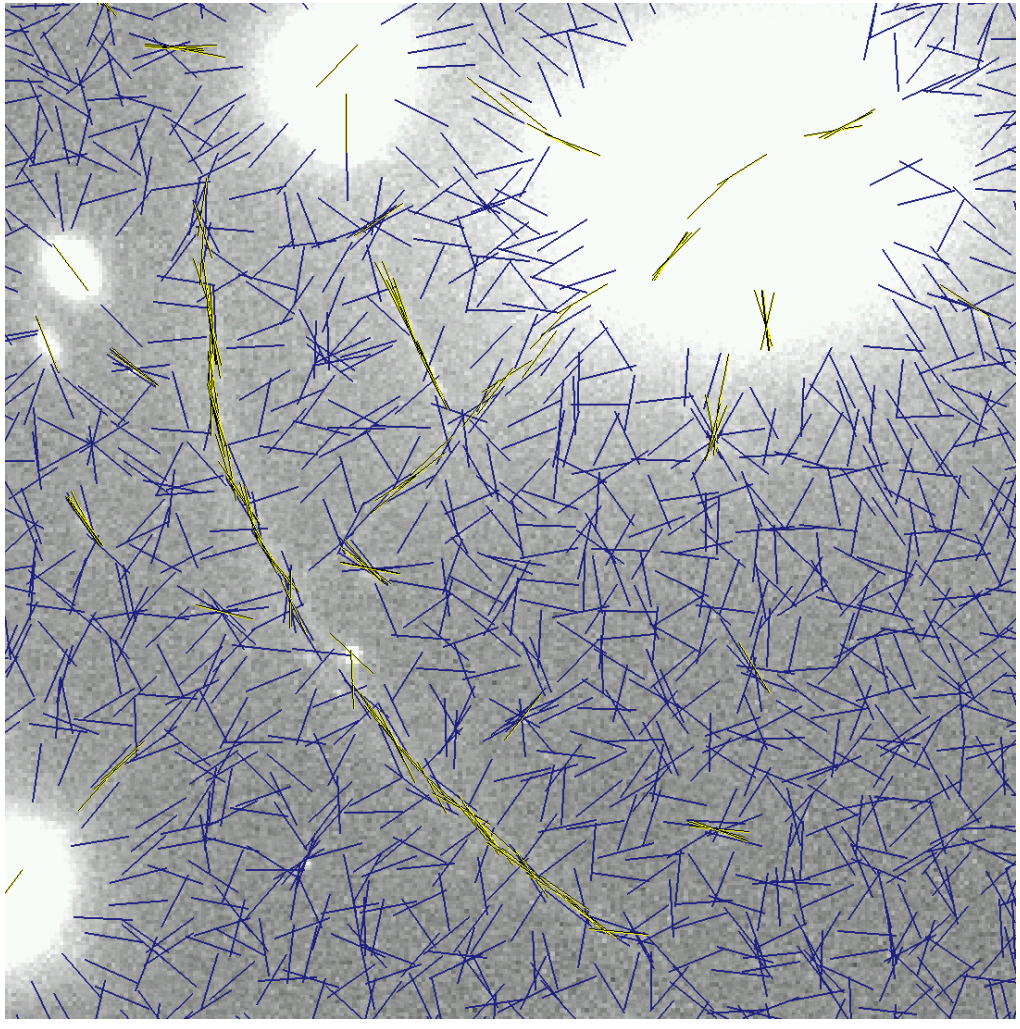

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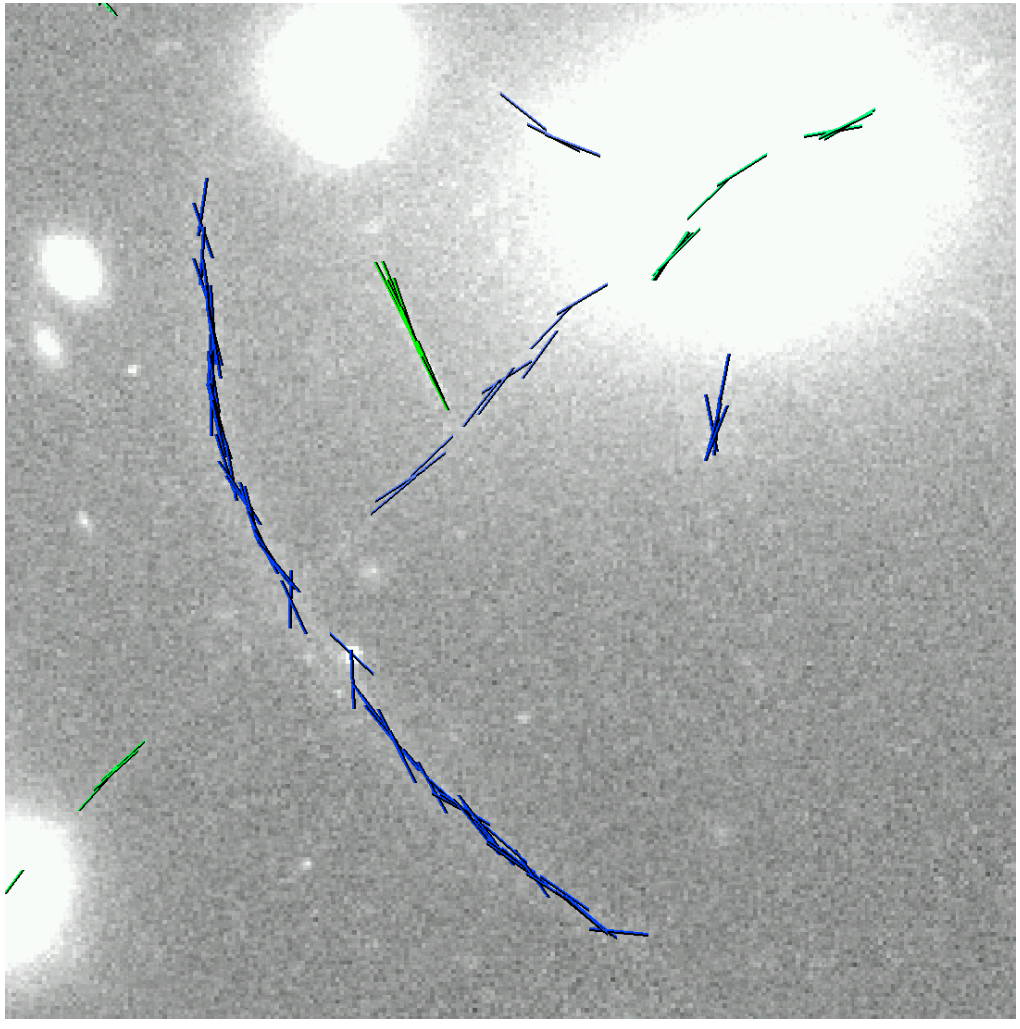
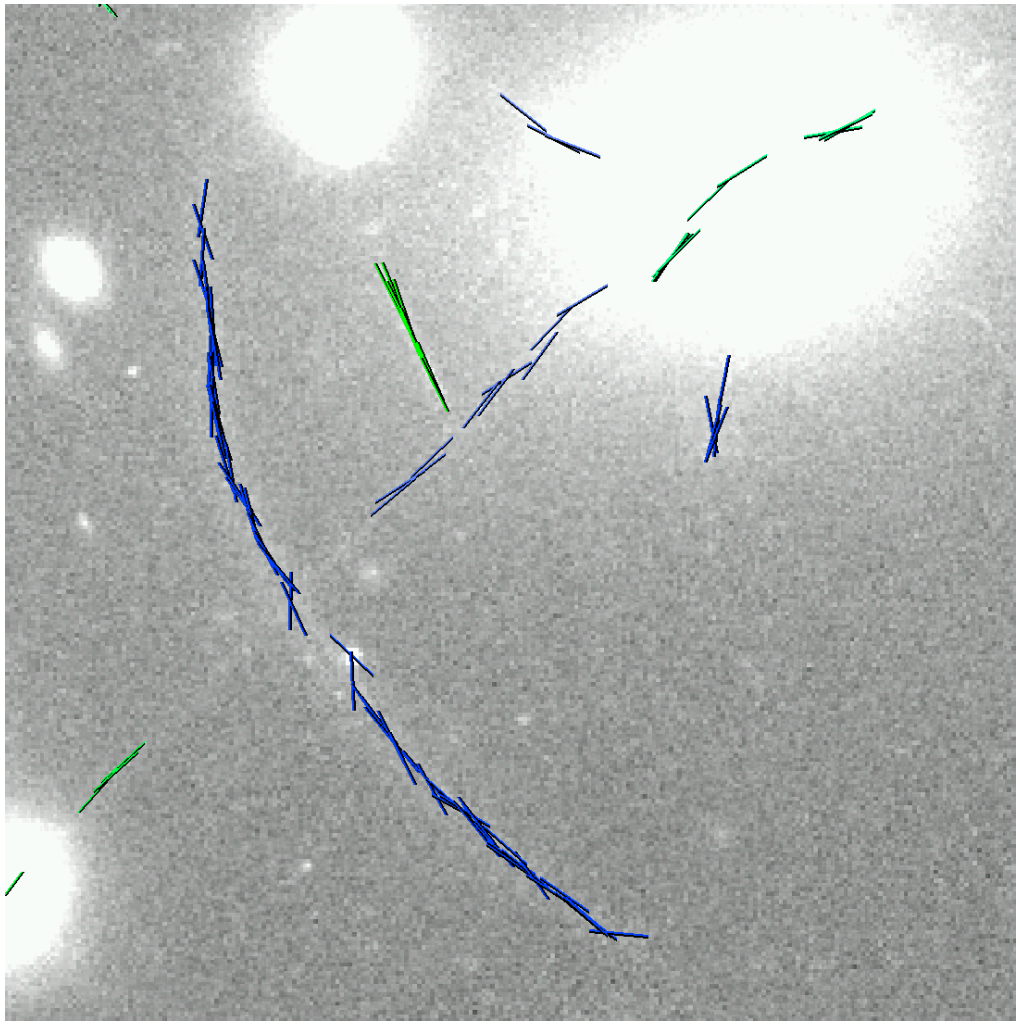


- basic object filter: minimal cellcount and diameter
- generate linear graphs following arc ridgeline



objects:

unsorted sets of cells

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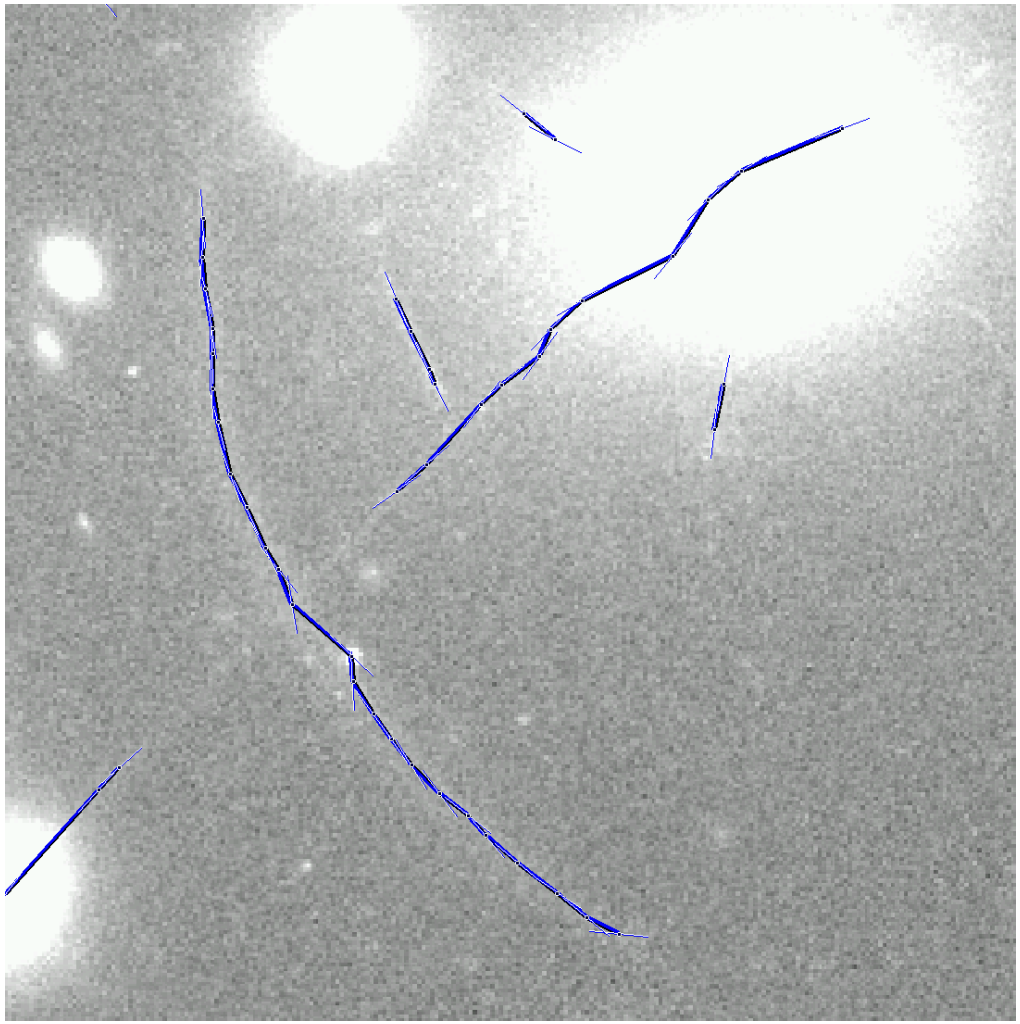

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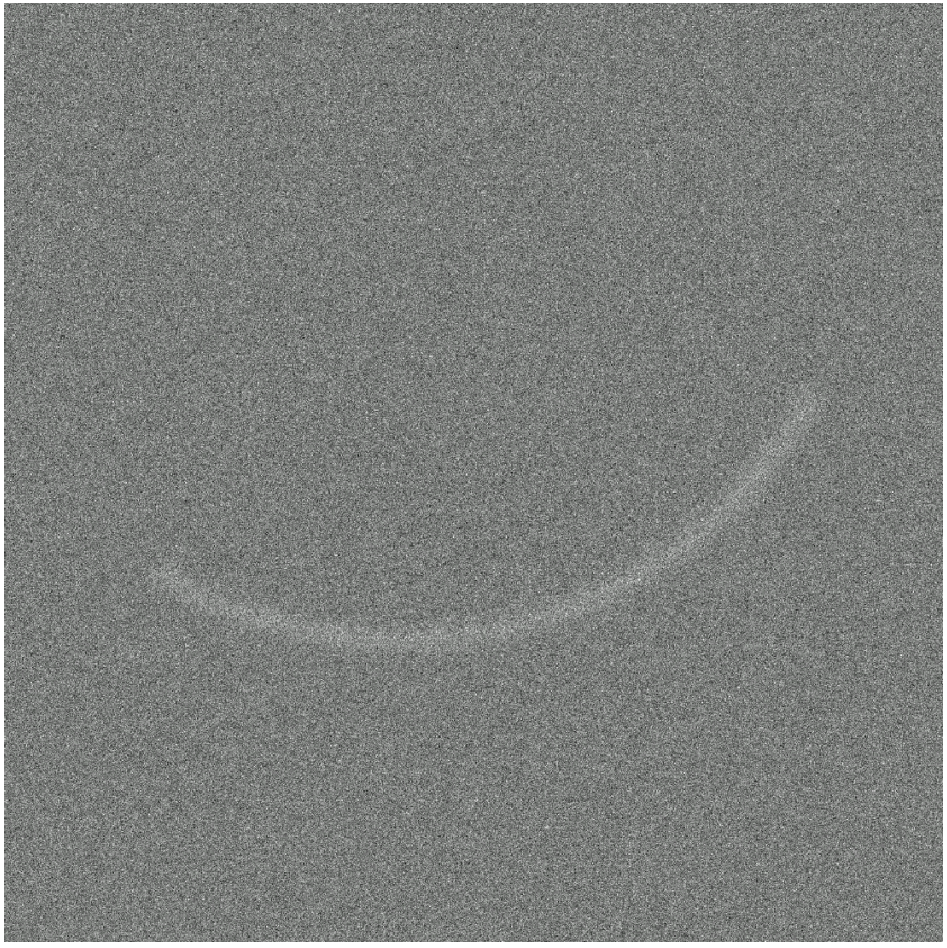
unsorted sets of cells

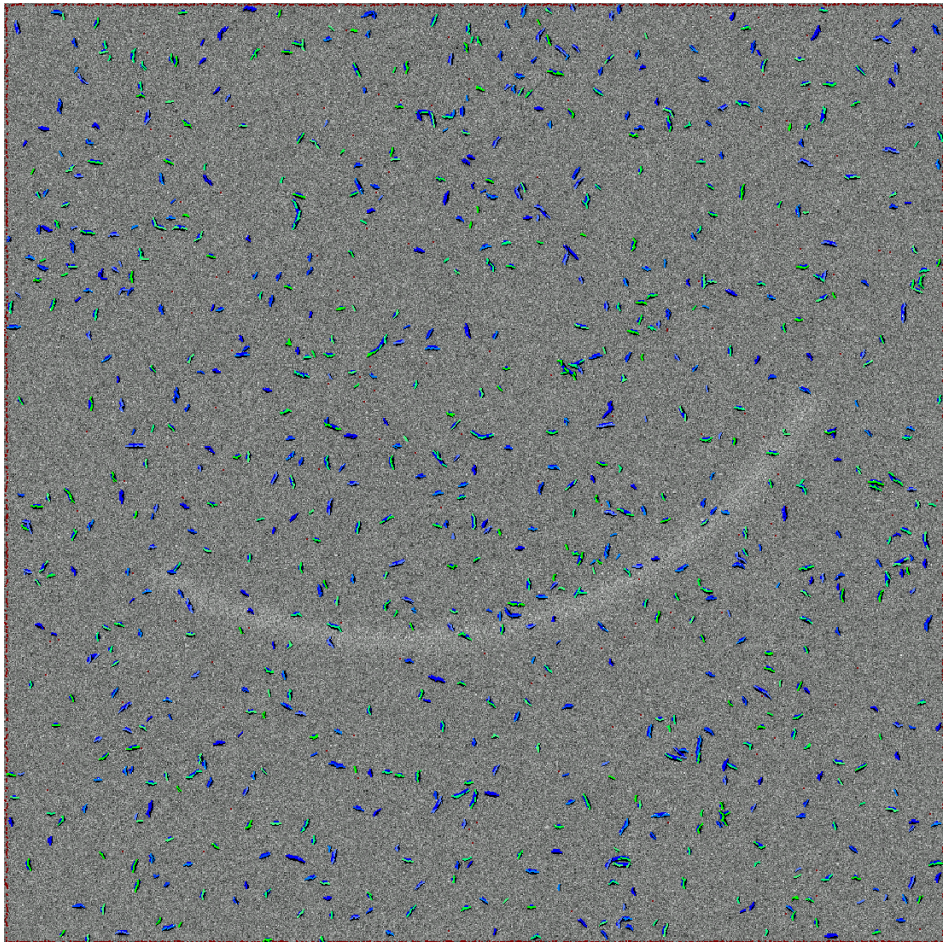
Spurious detections caused by several types of image features:

- Poissonian noise / pixel correlation
- galaxies
- spikes and blooming
- point sources



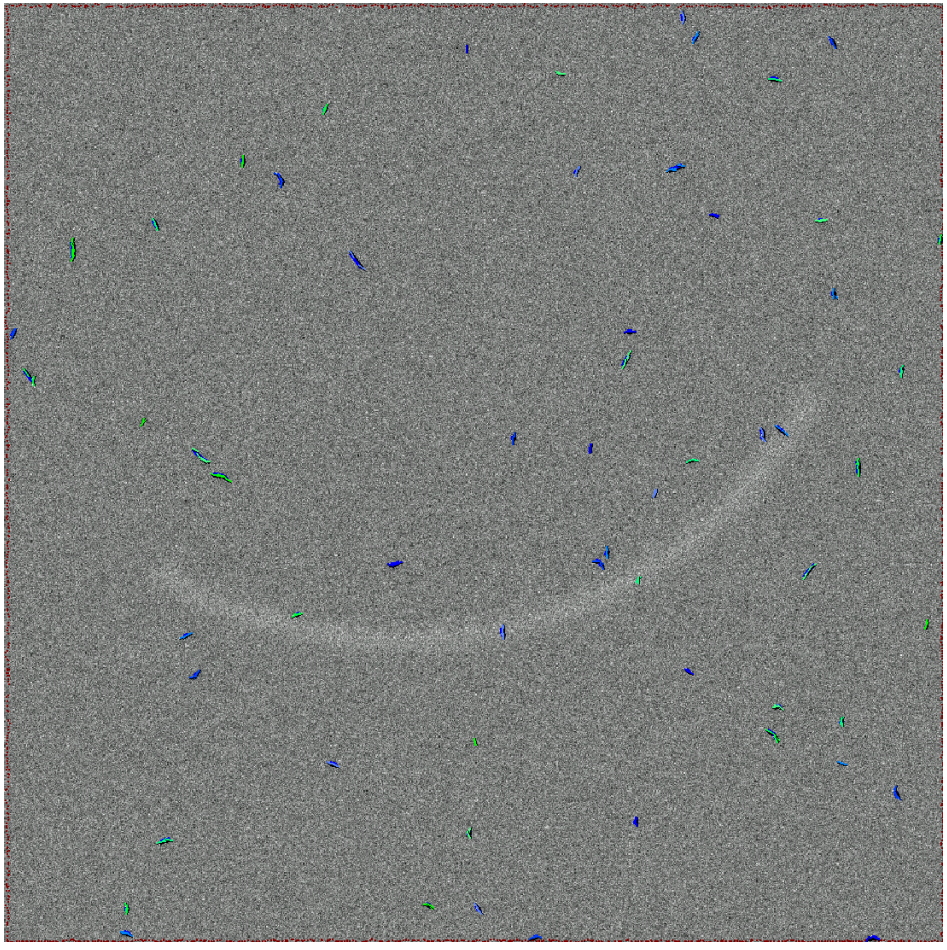
Spurious detections caused by several types of image features:

- Poissonian noise / pixel correlation scale size 5: 715 objects
- galaxies
- spikes and blooming
- point sources



Spurious detections caused by several types of image features:

- Poissonian noise / pixel correlation scale size 7: 49 objects
- galaxies
- spikes and blooming
- point sources



Spurious detections caused by several types of image features:

- Poissonian noise / pixel correlation scale size 9: 2 objects
- galaxies
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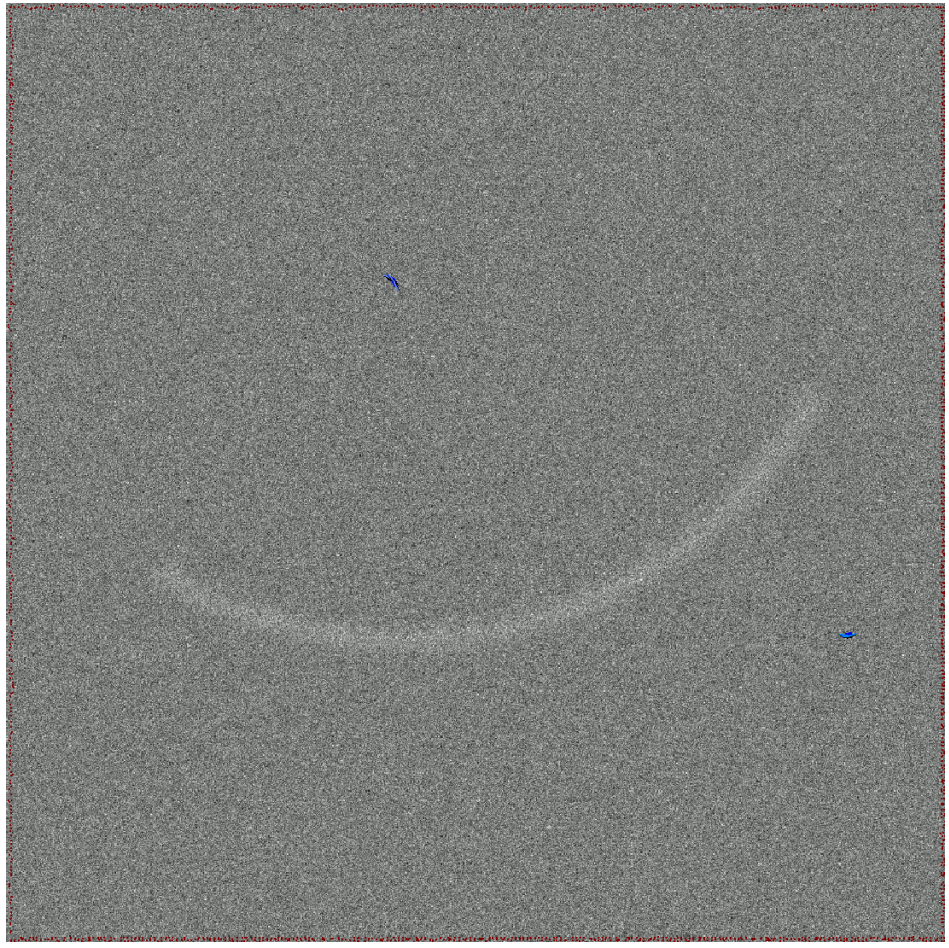
- point sources



Spurious detections caused by several types of image features:

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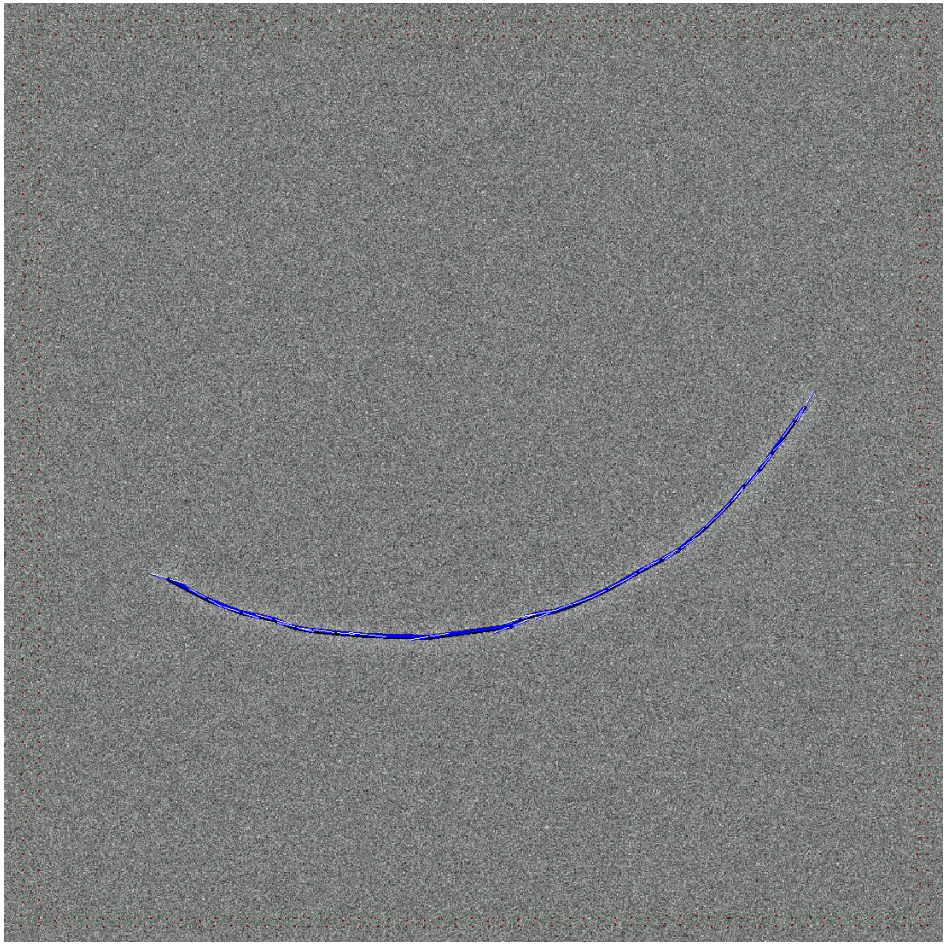

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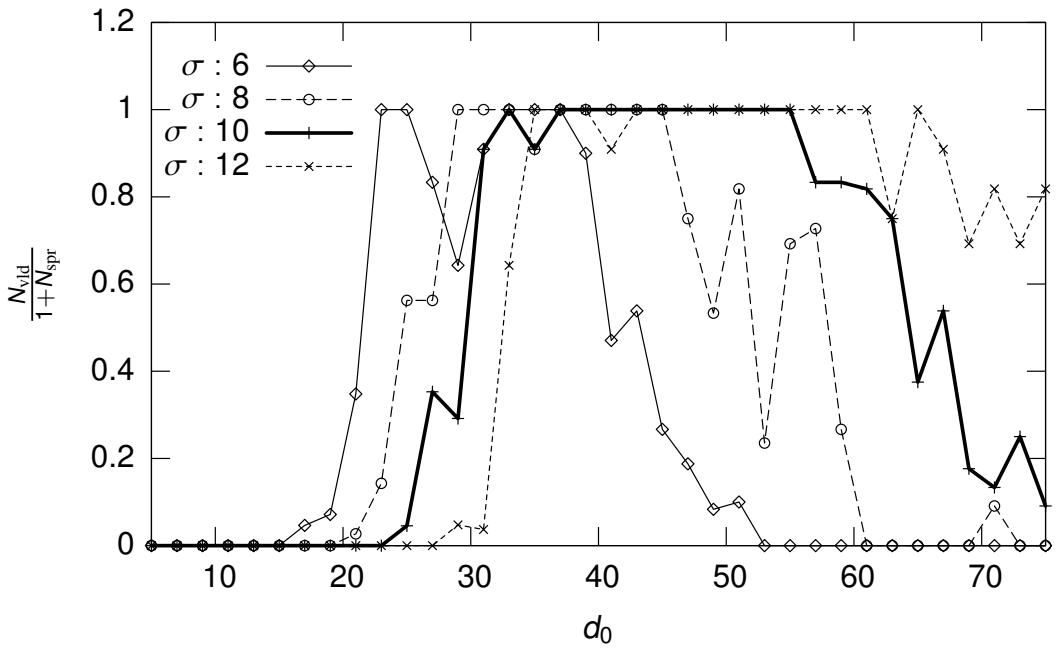

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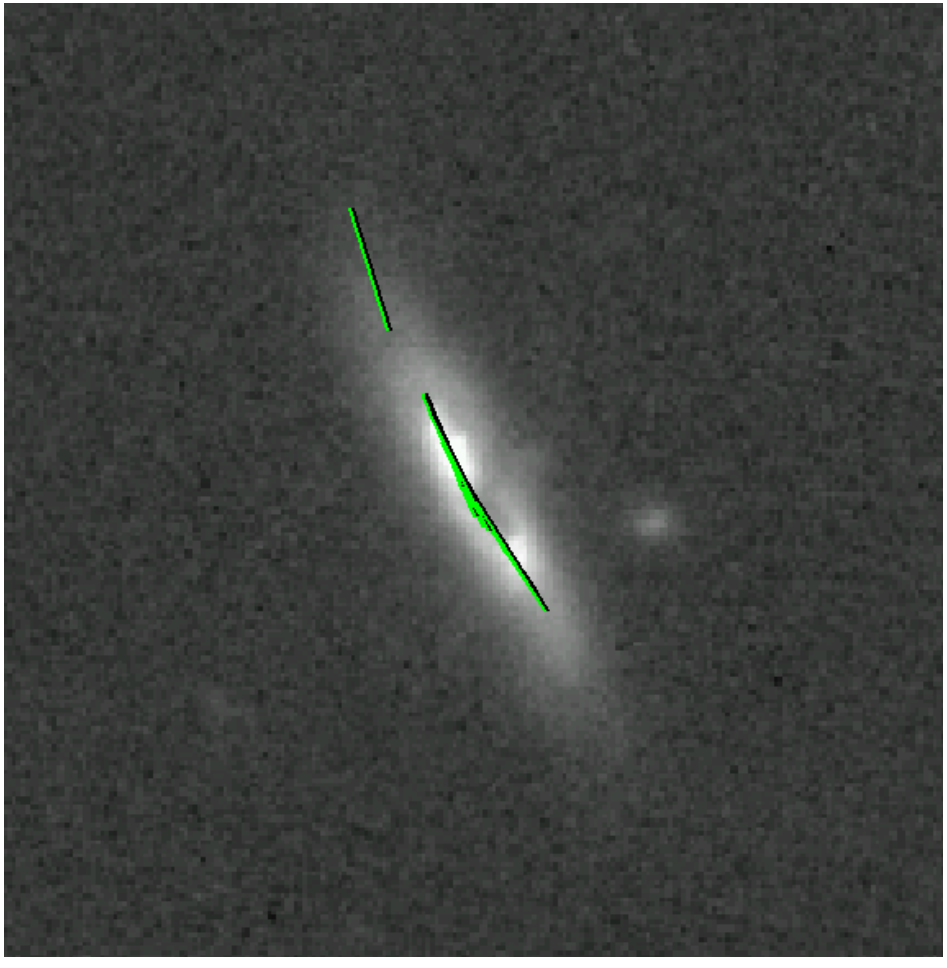

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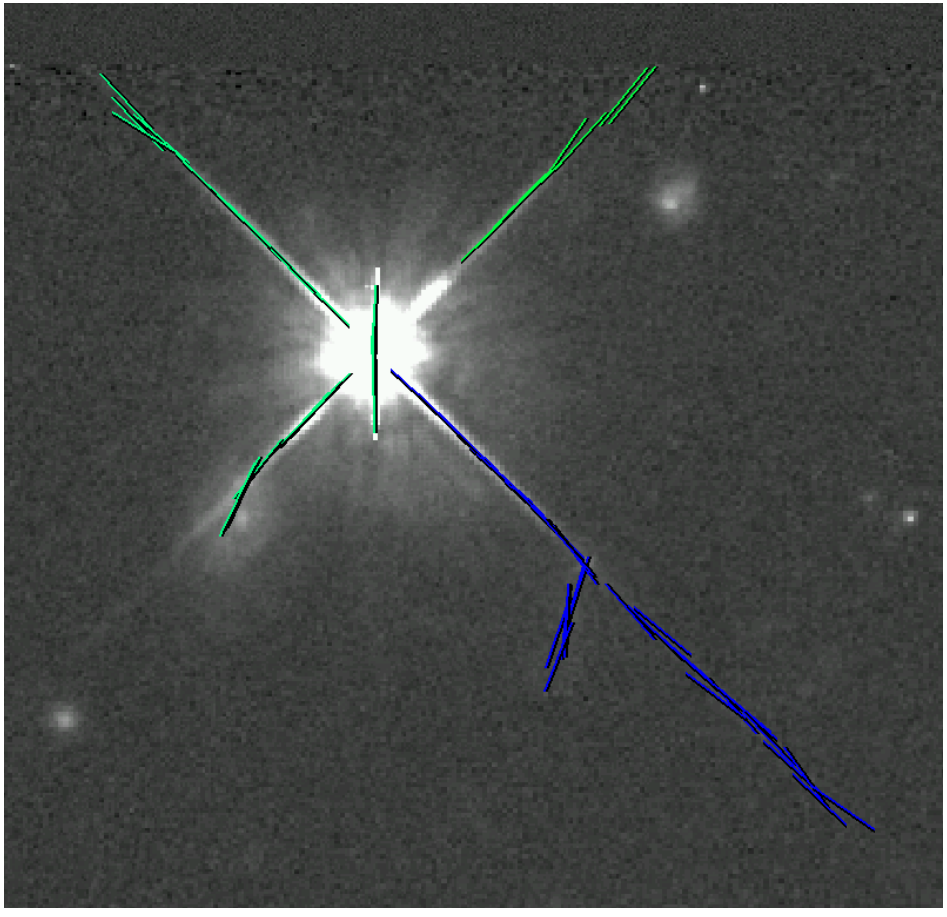

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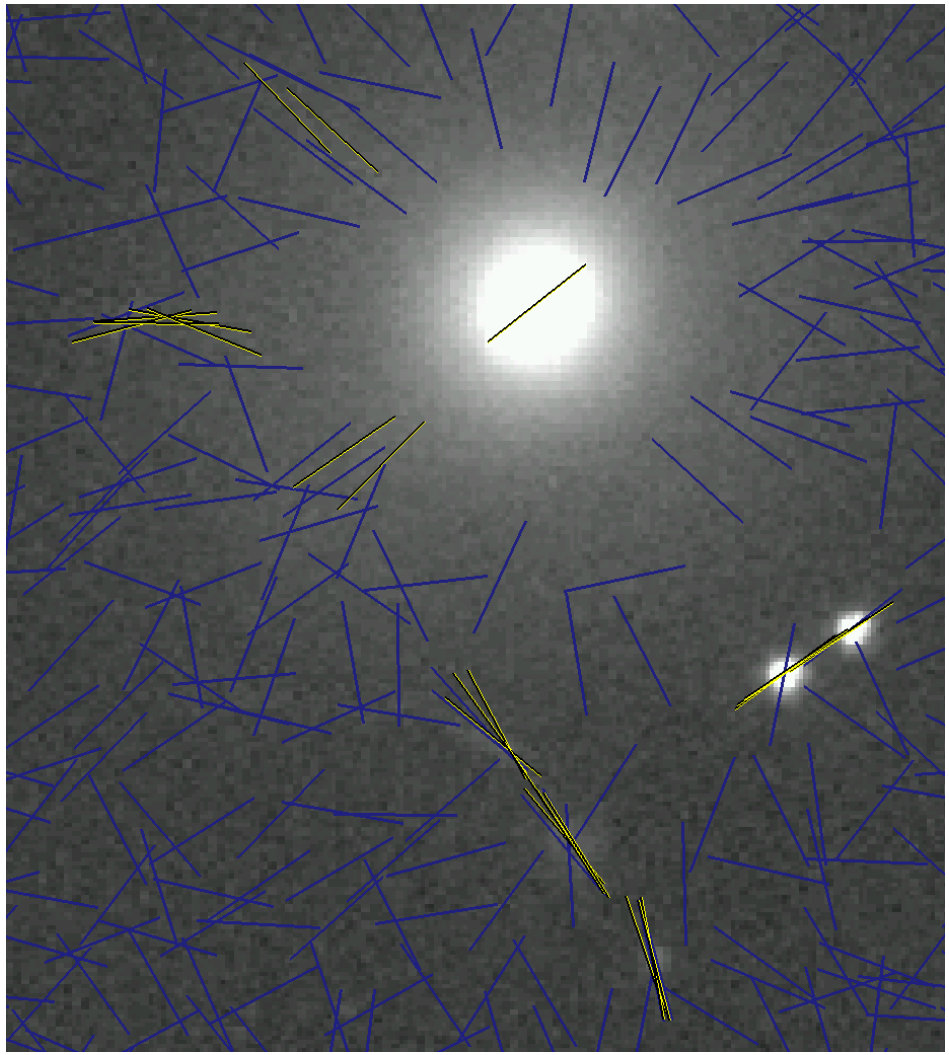

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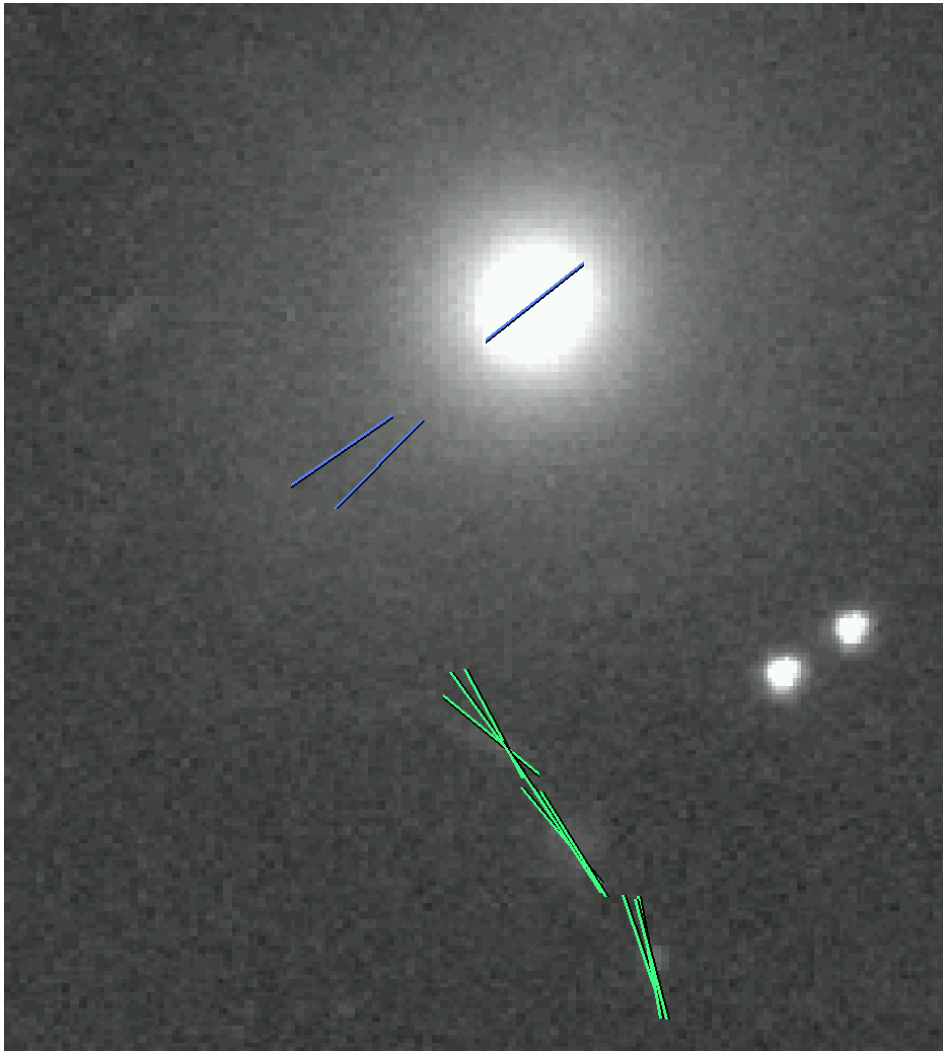
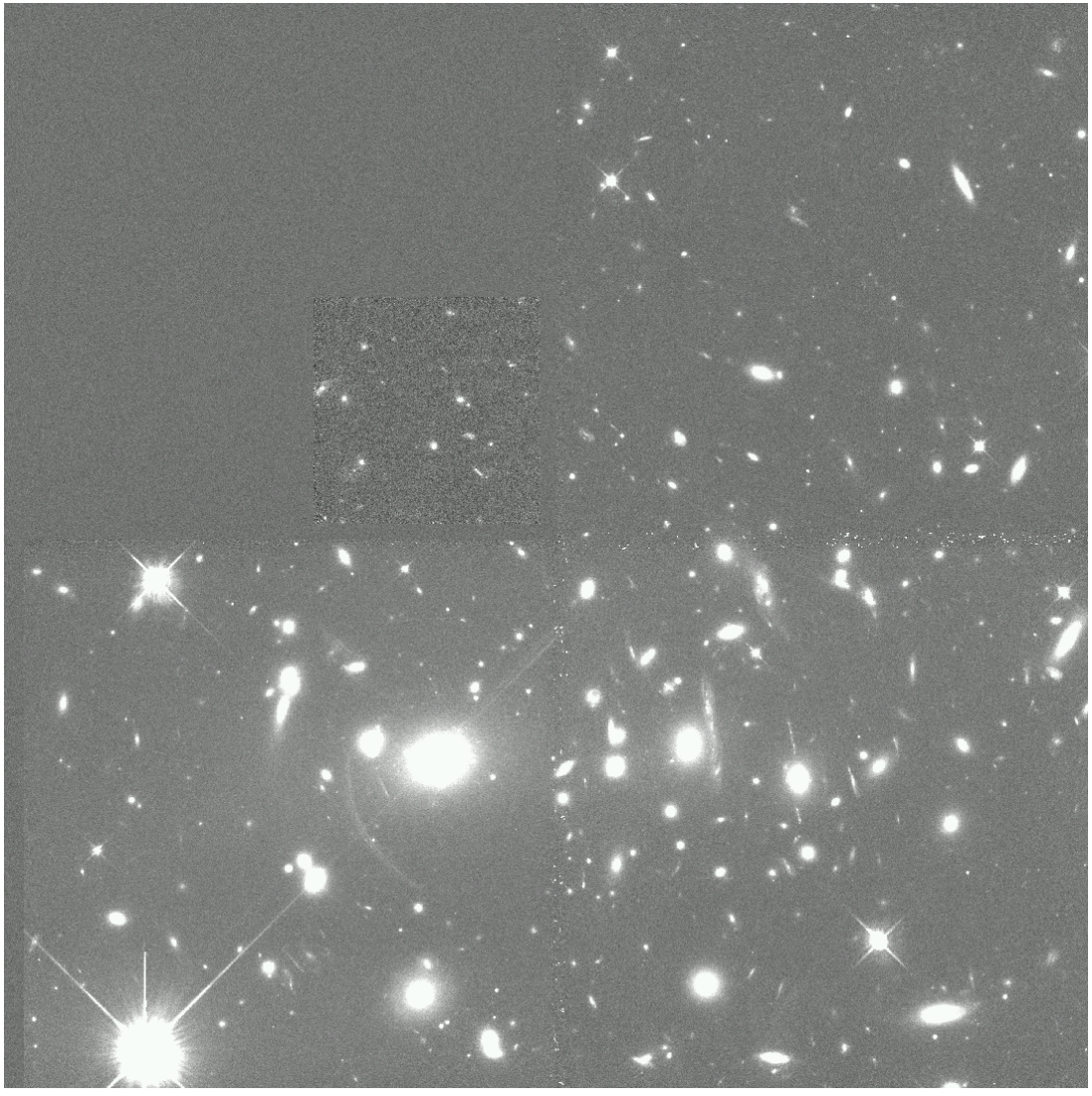


- post processing to remove as many spurious detections as possible
- determination of detection efficiency using simulated images
- application to datasets

Abell2390 by HST WFPC2

Processing time approx. 2.7s on 2.26GHz CPU



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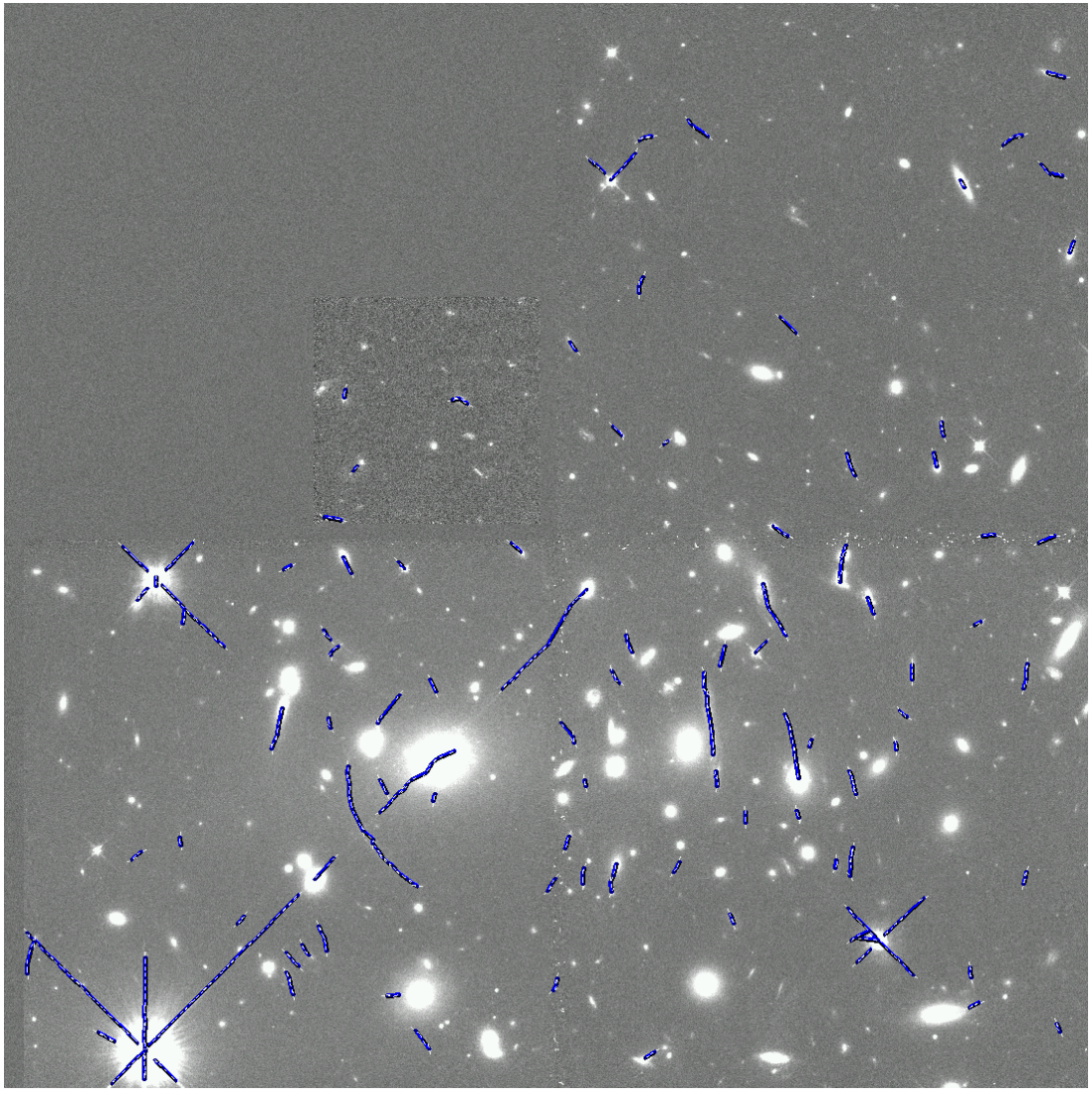
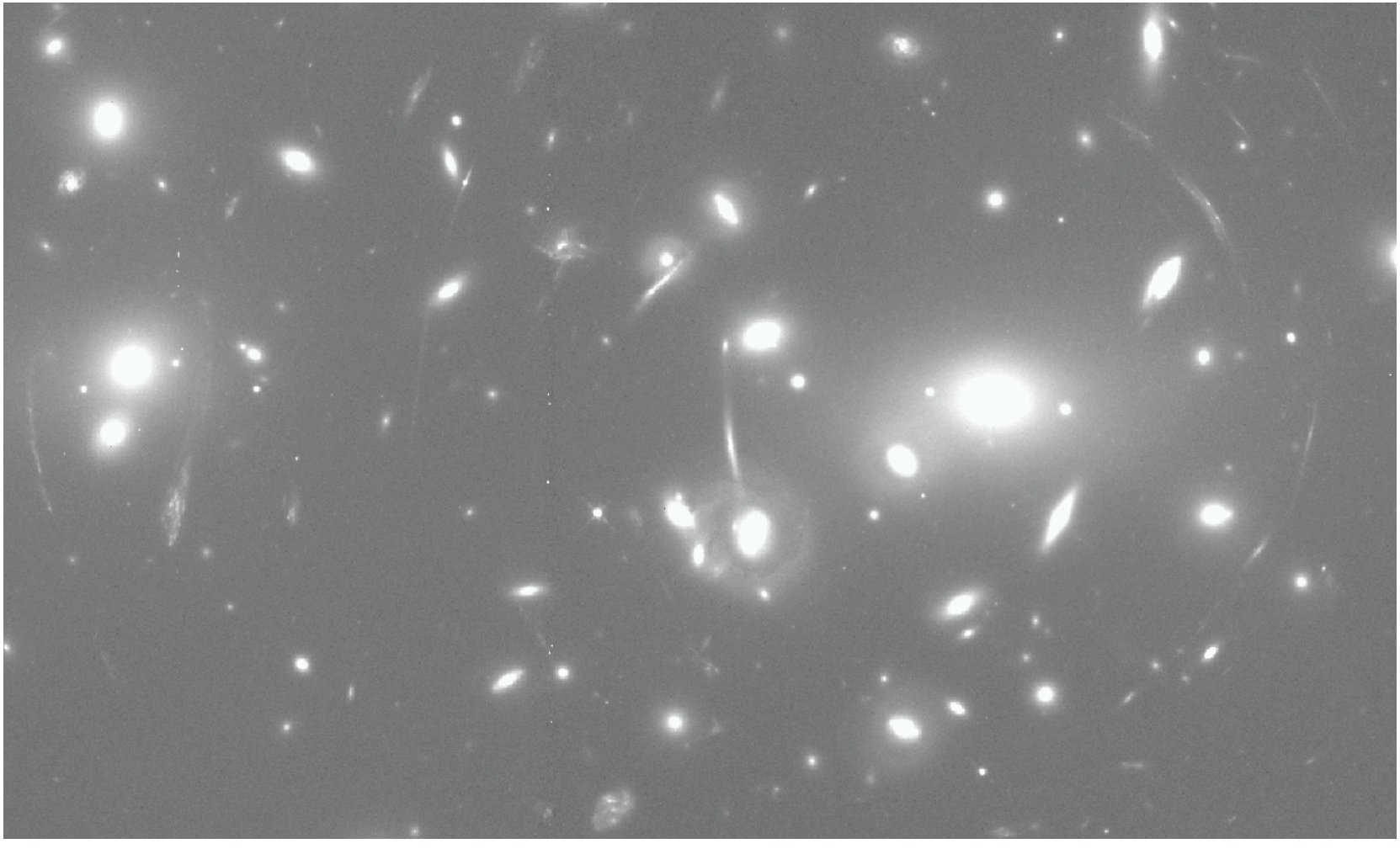
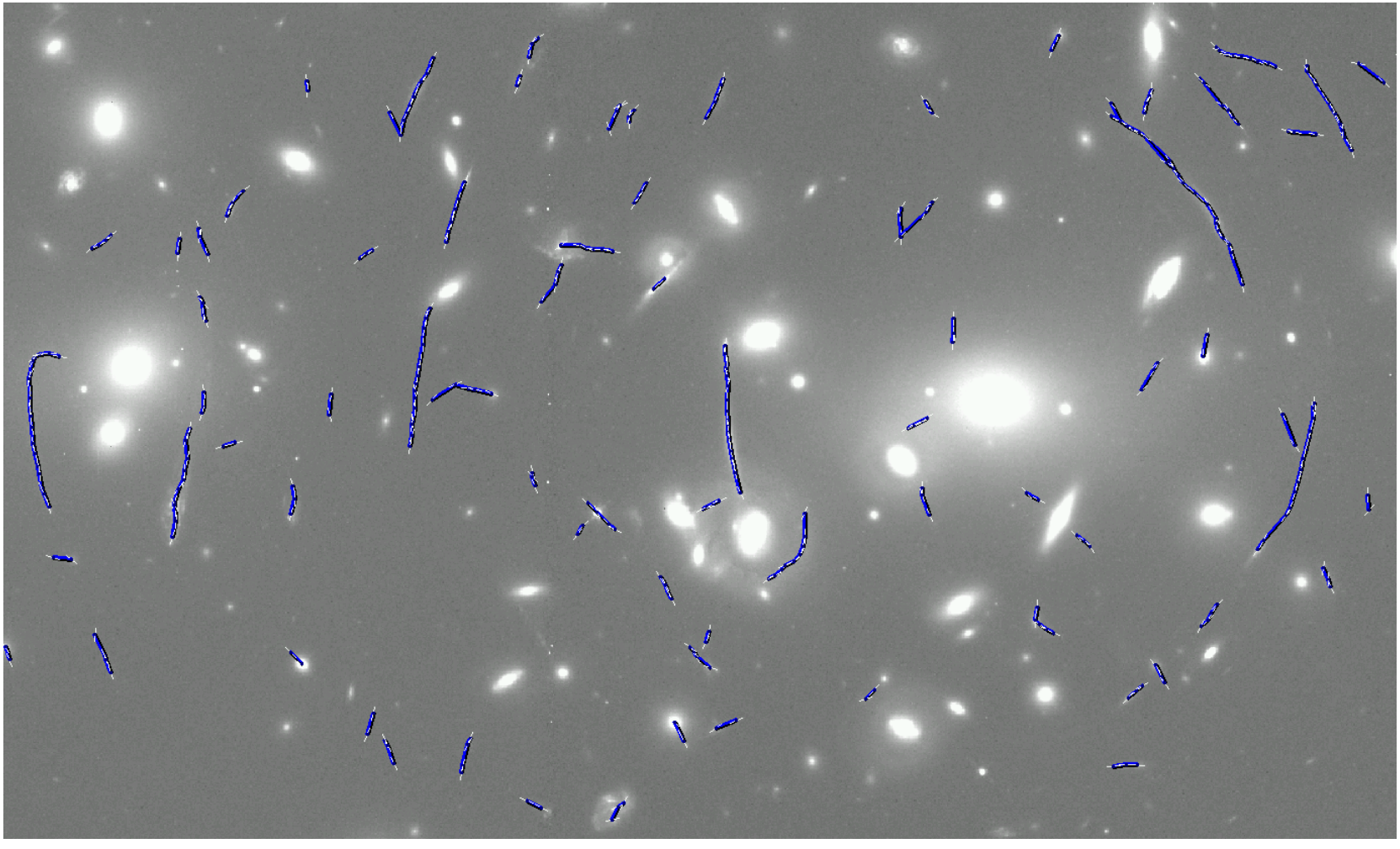


HST / WFPC2



HST WFPC2 image of Abell2218 with several detected arcs.
Also several false positives.



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